MASTER OF SCIENCE IN APPLIED PHYSICS

LINE BROADENING ANALYSIS OF MPD THRUSTERS

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Spectroscopic analysis of the cathode jet of a model coaxial magneto-plasma dynamic (MPD) thruster is conducted to determine electron density and temperature downstream from the cathode. H_β line profiles were scanned from an argon-hydrogen plasma generated in the cathode test facility of the NASA Jet Propulsion Laboratory in Pasadena, CA. A computer program was written in DL to determine the profile Doppler- and Stark half widths, which were used to determine temperature and electron density, respectively. Three sets of data from the cathode test facility were taken, while varying operating voltage, current, hydrogen/argon ratio, and pressure. Radial profiles for electron density and temperature were determined within the cathode jet. Generated plasmas ranged in electron density and temperature from approximately $N_e = 2\text{x}10^{14}$ cm^{-3} at 5000 K (0.43 eV) to $4\text{x}10^{14}$ cm^{-3} at 15600 K (1.3 eV). It was determined that radial density and temperature distribution within the cathode jet are essentially uniform.

BORO-SILICATE POLYCAPILLARY LENS FOR COLLIMATION OF X-RAYS

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The purpose of this thesis is to investigate the collimation of x-rays produced by transition radiation using the Naval Postgraduate School (NPS) Electron Linear Accelerator. These measurements support the theory that x-rays can be focused using a boro-silicate array of polycapillaries consisting of 258 bundles with 1387 micro-channels each. A 90 MeV electron beam incident upon a non-resonant mylar stack formed transition radiation spatially distributed in an annular cone. The electron beam was deflected 30 degrees using a rare earth permanent magnet. The diverging x-rays incident upon the lens array were transported through total external reflection and directed out of the array onto a phosphor screen. A digital camera recorded the phosphorescing image of the screen. Pixel intensity was analyzed to determine x-ray intensity as a function of two dimensional spatial distribution.

Column average profiles of the pixel intensity show that the transition radiation intensity retains its Gaussian distribution after being redirected from a diverging beam into a mostly parallel beam. The intensity of the x-rays decreased by a factor of 0.72 due to the obstructed area at the face of the array and to imperfect admittance of the diverging x-ray cone into the polycapillary array.

NON-ELECTRO-OPTIC METHODS OF HIGH FREQUENCY LASER MODULATION

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Two high frequency, non-electro-optic methods for modulating the intensity of a laser are examined theoretically and experimentally. The first modulation technique makes use of the Zeeman effect. Under an applied DC magnetic field, a splitting into two lines or three lines occurs. Modulation rates of 200 MHz have been proven possible with this technique. In the second technique, the properties of self-phase modulation of a monochromatic light are explored. For a high intensity beam, the optical path of a beam can be altered due the dependence of the phase on intensity. Thus two coherent beams of light of different intensity can be made to constructively or destructively interfere even if the physical paths are identical. In a configuration called a nonlinear-optical loop mirror, the output beam is amplitude modulated by linear variations in time of the total input power. A new design for a variable X-coupler, a key element of the loop mirror, is presented. Applications of high frequency modulators to test a theory of the AM-FM conversion of monochromatic light in fibers, to improve pulse rate control during target acquisition, and to high speed communications are discussed.

CONSTRUCTION OF A CONTINUOUS WAVE FREQUENCY MODULATION SENSITIVE LASER RADAR FOR USE IN TARGET IDENTIFICATION

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This thesis covers the theory, design and construction of a continuous wave (CW) frequency modulation sensitive laser radar. Using a commercially available CO_2 laser, optics and electronics, a CW frequency modulation sensitive laser radar was constructed and tested under laboratory conditions. The theory of each component in the laser radar is covered as well as the configuration and design of the radar. Design of a target that enabled measurement of the laser radar's capabilities was also completed. The laser radar was able to accurately measure a target's vibrational frequency and amplitude for amplitudes greater than 40 nm. The theoretical range of the designed laser radar is over 6 km. An improved optical design that allows a theoretical range of over 9 km is also presented. Applications of target identification are discussed.

INSTRUMENTATION AND MEASUREMENT OF A THERMOACOUSTICALLY DRIVEN THERMOACOUSTIC REFRIGERATOR

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This thesis is written to document the design, instrumentation and initial operation of a thermoacoustically driven thermoacoustic refrigerator. This design combines a quarter wavelength acoustic motor and a quarter wavelength acoustic refrigerator in a common resonator. Electrically generated heat provides power to the acoustic motor, producing a standing pressure wave, which is used by the refrigerator to produce cooling power. Several techniques are employed in the design to increase the efficiency of both the driver and the refrigerator compared to previous designs. A detailed description of the design and calibration of the required measurement instrumentation is provided. Finally, some initial driver data is presented.

MASTER OF SCIENCE IN APPLIED PHYSICS

ACOUSTIC CASIMIR EFFECT

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In 1948, Hendrick Brugt Gerhard Casimir predicted that two closely spaced uncharged conducting plates in vacuum would be mutually attracted. This attractive force is an indirect manifestation of the quantum electromagnetic zero point field (ZPF). When the indirect manifestations of the ZPF are interpreted as due to radiation pressure, acoustic noise can provide an excellent analog to investigate the Casimir effect as well as other effects due to the ZPF. Force measurements between two parallel plates are performed in an acoustic chamber with a broadband noise spectrum within a 5-15 kHz band and an intensity of 133 dB (re 20 μPa). When the results are compared with the appropriate theory, very good agreement is obtained. Applications of the acoustic Casimir effect to noise transduction can provide new means to measure background noise. Because attractive or repulsive forces can be obtained by adjusting the noise spectrum or the plate geometry, a non-resonant method of acoustic levitation is also suggested.

DESIGN, DEVELOPMENT, AND TESTING OF AN ULTRAVIOLET HYPERSPECTRAL IMAGER

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This research involved the development of an ultraviolet (UV) hyperspectral imager. A hyperspectral image is a three dimensional image in which two of the dimensions provide spatial information and the third provides spectral information. In an effort to minimize the cost of this experiment, the NPS Middle Ultraviolet SpecTrograph for Analysis of Nitrogen Gases (MUSTANG) instrument was modified to function as a hyperspectral imager. This required the design, fabrication, and testing of hardware and software to coordinate the operation of a two dimensional, charge coupled device (CCD) detector with a servo-controlled scanning mirror. Control and synchronization of scanning mirror and image collection was accomplished by software (written in Borland C++) run from an Intel microprocessor based PC. The benefits of a UV hyperspectral imager are primarily in the area of Support to Military Operations (SMO). There are two principal applications: 1) target identification, and 2) battle damage assessment. Additionally, this instrument has dual use applications, namely, 1) redirection of jet aircraft to avoid the foreign object damage (FOD) hazards presented by volcanic ash clouds through analysis of the absorption of solar UV radiation by the sulfur dioxide ($S0_2$) gas associated with volcanic ash, and 2) forest fire detection.

ROBOT WARS SIMULATION

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Naval Postgraduate School (NPS) Combat Systems students learn about robots and autonomous weapons during group design projects in the SE 3015 course sequence. This sequence is designed to provide experience in combat systems development. The capstone project is the Robot Wars Competition, where pairs of student-designed autonomous robots battle each other. This thesis extends this competition into the arena of simulation and modeling. Our motivation is to further

students' understanding of the strengths and weaknesses of computer modeling and simulation in combat systems design and testing.

This thesis creates a simulation foundation of the Robot Wars Competition. The simulation has been designed in two main parts, a C++ program that manipulates the Simbots on the playing field and generates data files of their movements, and a 3D graphical visualization that allows the user to see the Simbots in action. The C++ program uses a Simbot class to instantiate two Simbots which are composed of three basic components: base, optics and weapons. The graphics portion uses data files created in the main simulation and displays in 3D animation. The simulation correctly replicates the logical and physical aspects of the robot competition. Future research on the physical aspects of the component parts and the graphics package can be integrated with this foundation.

MODELING THE QUANTUM DOT

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Much of the progress in solid-state microelectronics has come from the continued reduction in size of the transistors that make up integrated circuits (ICs), having dropped by a factor of 10 in the last decade to where minimum device geometries have reached approximately 350 nanometers in mass production. Continued improvements in ICs will require a device technology that can be scaled down to the sub-100 nanometer size regime. There, the quantum mechanical nature of the electron becomes strongly evident, and new design tools are required for a nano-electronic semiconductor technology. The combined scaling and speed advantages of these new devices could portend orders of magnitude increases in the functional performance of future-generation ICs.

Quantum device performance is extremely sensitive to small variations in design parameters. Accurate theoretical modeling is therefore required to guide the technology development. Conventional device design tools are based on classical physics, and do not incorporate quantum effects. New design tools are required to explicitly account for the quantum effects that control charge transport at the nanometer scale. To further understand and develop nanoscale device technology, this thesis will model the potential energy function in a quantum dot, a nanostructure in which electrons are quantum-mechanically confined in all three dimensions and which represents the inevitable result of continued downscaling of semiconductor devices.

EXPERIMENTAL AND NUMERICAL INVESTIGATIONS OF THE GAUSSIAN SUPPRESSION OF SOUND BY SOUND

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In this work we report on experimental and numerical investigations of the attenuation of a small-amplitude signal due to its interaction with high intensity, band limited sound whose spectrum consists of up to four discrete peaks. We probe the "thermodynamic limit" for different configurations of the spectral components. In particular the attenuation of the signal is investigated for both equally and unequally spaced spectral components, as well as different phase relations among them. The possibility of collective modes is also explored by measurements of the phase change in the signal downstream due to the presence of discrete noise.

THE DESIGN OF THE NAVAL POSTGRADUATE SCHOOL'S ULTRAVIOLET IMAGING SPECTROMETER (NUVIS)

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Hyperspectral imaging spectrometers are remote sensing instruments capable of producing an image cube comprised of a two-dimensional scene and the corresponding spectra of each scene element remote sensing is growing in civilian applications and support of military operations. Civilian applications vary from plant species identification, stress measurement, leaf water content and canopy chemistry to geological identification and mapping. Military applications include target identification and classification, bomb damage assessment, terrain or area utilization and rocket plume identification.

This thesis describes the fabrication and alignment of the NPS Ultraviolet Imaging Spectrometer (NUVIS). NUVIS is a hyperspectral imaging spectrometer designed to investigate the added value of the ultraviolet region of the spectrum. The spectrometer is comprised of a telescope assembly using an off-axis parabolic mirror, a slit, a flat-field imaging diffraction grating and a camera assembly. This is the first part of a continuing project to build, test and use this sensor for support of military operations.

OCEAN WAVE DATA ANALYSIS USING HILBERT TRANSFORM TECHNIQUES

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A novel technique to determine the phase velocity of long-wavelength shoaling waves is investigated. Operationally, the technique consists of three steps. First, using the Hilbert transform of a time series, the phase of the analytic signal is determined. Second, the correlations of the phases of analytic signals between two points in space are calculated and an average time of travel of the wave fronts is obtained. Third, if directional spectra are available or can be determined from time series of large array of buoys, the angular information can be used to determine the true time of travel. The phase velocity is obtained by dividing the distance between buoys by the correlation time. Using the Hilbert transform approach, there is no explicit assumption of the relation between frequency and wavenumber of waves in the wave field, indicating that it may be applicable to arbitrary wave fields, both linear and nonlinear. Limitations of the approach are discussed.

HIGH-ACCURACY DISTRIBUTED SENSOR TIME-SPACE-POSITION INFORMATION SYSTEM FOR CAPTIVE-CARRY FIELD EXPERIMENTS

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Operational EW test and evaluation experiments require that the position of the aircraft and other moving objects on the range be known precisely as a function of time. Terminal Time-Space-Position Information (TSPI) Systems involve the range platforms interacting at close distances and therefore require precise trajectory information over a restricted volume of space. Terminal TPSI systems are used for tactics evaluation and the evaluation of simulated weapons firings (e.g., captive-carry hardware-in-the-loop missile simulators). Distributed sensor TSPI systems consist of two or more measurement sensors located some distance from each other. Each sensor makes a measurement of target angle and range. Distrib-

uted sensor systems are more complex than single-point systems involving multiple hardware installations, complex mathematical computations to extract coordinate information, synchronization of multiple measurements and calibration of a number of different stations.

This paper presents a novel distributed sensor TSPI architecture that provides precise positioning information of the target relative to a fixed inertial coordinate system. The architecture efficiently integrates the information from an inertial navigation system (INS), a global positioning system (GPS) and any number of distributed RF sensors which may be located onboard a captive-carry aircraft. The significance of this work is that by knowing the target's position in a fixed inertial frame of reference (derived from the integration process) an evaluation can be made as to the effectiveness of any electronic attack or off-board decoys that might have been launched during the field test scenario. The induced INS, GPS and sensor noise and the corresponding errors due to the integration process are evaluated numerically as a function of the weapon system being used. The accuracy in the targeting information is also quantified and compared with the true expected values.

CASIMIR ACOUSTICS

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When the indirect manifestations of the electromagnetic ZPF are interpreted as due to radiation pressure, acoustic noise can render an excellent analog to probe previous as well as recently proposed behavior. An acoustic chamber for isotropic and homogeneous acoustic noise of controllable spectral shape has been built. The noise can be driven up to levels of 130dB (re 20 μPa) in a band of frequencies up to 50 kHz wide. When driving the system with broadband noise, it will be used: (i) to test the Galilean invariance of a spectral shape proportional to the square of the frequency, (ii) the force of attraction between parallel plates (analog to Casimir force), (iii) the acoustic radiation emitted by a cavity that is made to oscillate at high frequencies (analog to the proposed Casimir radiation), (iv) the change in the frequency of oscillation of a pendulum as the noise intensity is varied (analog to the proposed origin of inertia), and (v) the force of attraction between two spheres due to the acoustic shadow that each one casts onto the other (analog to van der Waals force and the proposed origin of gravitation).

FRAGMENT IMPACT ON A CHEMICAL WARHEAD (U)

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Current U.S. strategic policy has placed significant emphasis on Theater Missile Defense (TMD); problems associated with high-altitude intercept and destruction of threat missile Systems are extensive. The actual missile-to-missile encounter is anticipated to occur anywhere from exoatmospheric altitudes to very low endoatmospheric altitudes. Conduct of experiments to simulate these conditions at these altitudes is hampered by the inability to produce, at ground level, the velocity and atmospheric conditions associated with actual missile-to-missile encounters. However, experiments have been conducted at a reduced scale, for velocity and atmospheric conditions, for both the interceptor and target.

The objective of this thesis is to evaluate the role target obliquity and hole size have on fragment lethality of TMD interceptors. Also, the ability of the fragment model within the Parametric Endo/Exoatmospheric Lethality Simulation (PEELS) is evaluated for representation of the above parameters. In order to evaluate the significance of obliquity on a fragment intercept and the ability of PEELS to accurately represent that intercept, this thesis will first examine the intercept conditions of two different fragmenting warhead missiles, one directional and one aimable, against a threat chemical payload ballistic missile. Aimable warheads focus the fragment spray directly on the target, thereby increasing the probability

of hit and the probability of kill given a hit on the target. Directional warheads have charges placed around the warhead to direct the blast through the timing of the charges, thereby increasing the hit probability. Experiments relevant to the intercept conditions are analyzed to better understand the phenomeno- logy of fragment impact that occurs at these conditions. Next, the current Parametric Endo/Exothermic Lethality Simulation (PEELS) fragmentation methodology, produced by Kaman Sciences Corporation, is compared to the intercept conditions and experimental data. Finally, hole size in the aeroshell, produced by interceptor fragments will be examined to determine if enhanced lethality is obtained for the aimable fragmenting warheads.

HIGH FREQUENCY CHARACTERIZATION OF THE GSANGER LM0202P ELECTRO-OPTIC MODULATOR

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This thesis documents experiments conducted with the Gsanger LM0202P electro-optic modulator to achieve a high percentage modulation at 125MHz of an argon-ion laser. The laser was tuned to produce a single mode, linearly polarized light at 514.5 nm. The laser light was first passed through the electro-optic crystal modulator with no external electric field applied, and the frequency spectrum was observed to be the same as the frequency spectrum of the source laser. When an AC voltage with a frequency of 125 MHz was applied to the modulator sidebands were observed by using a Fabry-Perot interferometer. Further measurements were taken to determine the suitability of the LM0202P modulator over a large frequency range.

ALTERNATIVE PATHWAYS TO NUCLEAR WEAPONS PRODUCTION (U)

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CLASSIFIED ABSTRACT